PB83-117739

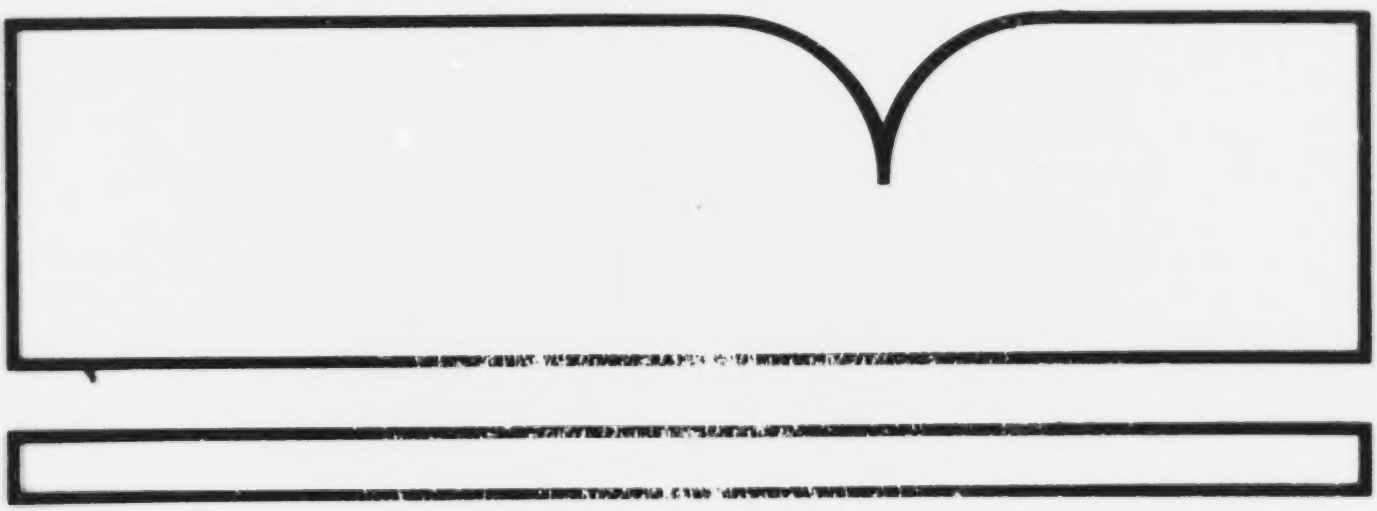
PAL-DS Model: The PAL Model Including Deposition and Sedimentation User's Guide

(U.S.) National Oceanic and Atmospheric Administration, Oak Ridge, TN

Prepared for

Environmental Sciences Research Lab.
Research Triangle Park, NC

Oct 82



U.S. Department of Commerce
National Technical Information Service
NTIS

PB83-117739

EPA-600/8-82-023
October 1982

PAL-DS MODEL: THE PAL MODEL INCLUDING DEPOSITION AND SEDIMENTATION

User's Guide

by

K. Shankar Rao and H. F. Snodgrass
Atmospheric Turbulence and Diffusion Laboratory
National Oceanic and Atmospheric Administration
Oak Ridge, Tennessee 37830

IAG-AD-13-F-0177-0

Project Officer

Jack H. Shreffler
Meteorology and Assessment Division
Environmental Sciences Research Laboratory
Research Triangle Park, North Carolina 27711

ENVIRONMENTAL SCIENCES RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711

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NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

TECHNICAL REPORT DATA (Please read Instructions on the reverse before completing)		
1. REPORT NO. EPA-600/8-82-023	2.	3. RECIPIENT'S ACCESSION NO. PB83-117739
4. TITLE AND SUBTITLE PAL-DS MODEL: THE PAL MODEL INCLUDING DEPOSITION AND SEDIMENTATION User's Guide		5. REPORT DATE October 1982 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) K. Shankar Rao and H.F. Snodgrass		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS ATMOSPHERIC TURBULENCE AND DIFFUSION LABORATORY NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION OAK RIDGE, TN 37830		10. PROGRAM ELEMENT NO. CCUL1A-03 0505 (FY-82) 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS ENVIRONMENTAL SCIENCES RESEARCH LABORATORY - RTP, NC OFFICE OF RESEARCH AND DEVELOPMENT U.S. ENVIRONMENTAL PROTECTION AGENCY RESEARCH TRIANGLE PARK, NC 27711		13. TYPE OF REPORT AND PERIOD COVERED 8/80 - 2/82 14. SPONSORING AGENCY CODE EPA/600/09
15. SUPPLEMENTARY NOTES		

16. ABSTRACT

PAL is an acronym for an air quality model which applies a Gaussian plume diffusion algorithm to point, area, and line sources. The model is available from the U.S. Environmental Protection Agency and can be used for estimating hourly and short-term average concentrations of non-reactive pollutants at multiple receptors from several sources of each type. PAL is intended to assess the impact on air quality, on scales of tens of meters to several kilometers, of portions of urban areas such as shopping centers, large parking areas, and airports. Level terrain is assumed, and pollutant removal processes are ignored.

This report is a supplementary User's Guide to a modified version of PAL, PAL-DS, model that utilizes Gaussian plume-type diffusion-deposition algorithms based on analytical solutions of a gradient-transfer model. The PAL-DS model can treat deposition of both gaseous and suspended particulate pollutants in the plume since gravitational settling and dry deposition of the particles are explicitly accounted for.

17. KEY WORDS AND DOCUMENT ANALYSIS		
a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
18. DISTRIBUTION STATEMENT RELEASE TO PUBLIC	19. SECURITY CLASS (This Report) UNCLASSIFIED 20. SECURITY CLASS (This page) UNCLASSIFIED	21. NO. OF PAGES 49 22. PRICE

EPA Form 2220-1 (9-73)

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ABSTRACT

PAL is an acronym for a model which applies a Gaussian plume diffusion algorithm to point, area, and line sources. The model can be used for estimating hourly and short-term average concentrations of non-reactive pollutants at multiple receptors from several sources of each type. PAL is intended to assess the impact on air quality, on scales of tens of meters to several kilometers, of portions of urban areas such as shopping centers, large parking areas, and airports. Level terrain is assumed, and pollutant removal processes are ignored.

This report is a User's Guide to the PAL-DS model that utilizes Gaussian plume-type diffusion-deposition algorithms based on analytical solutions of a gradient-transfer model. The PAL-DS model can treat deposition of both gaseous and suspended particulate pollutants in the plume since gravitational settling and dry deposition of the particles are explicitly accounted for. The analytical diffusion-deposition expressions listed in this report are easy to apply and, in the limit when pollutant settling and deposition velocities are zero, they reduce to the usual Gaussian plume diffusion algorithms in the PAL model.

This report outlines the modifications of the PAL computer program to include deposition. The information is oriented to the model user and the programmer. This report is not a complete User's Guide to the PAL-DS model; it should be used as a supplement to the original User's Guide for PAL.

This report was submitted in partial fulfillment of Interagency Agreement No. AD-13-F-0177-0 by NOAA's Atmospheric Turbulence and Diffusion Laboratory. This work, covering the period September 1980 to September 1981, was completed as of September 30, 1981.

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ACKNOWLEDGEMENTS

This report was prepared for the Office of Research and Development, Environmental Sciences Research Laboratory of the U.S. Environmental Protection Agency to support the needs of EPA's Office of Toxic Substances. This work was accomplished under interagency agreements among the U.S. Department of Energy, the National Oceanic and Atmospheric Administration, and the EPA. The authors are grateful to Dr. Jack Shreffler of ESRL for the opportunity to do this work, and for his interest and support, and Mr. William Petersen of ESRL for his valuable suggestions. The authors also express their appreciation and thanks to Miss Lynne Satterfield for computer assistance and Ms. Erma Yates for her expert technical typing and patient revisions.

SECTION 1

INTRODUCTION

PAL is an acronym for a Gaussian plume diffusion algorithm for point, area, and line sources. In the PAL model described by Petersen (1978), the algorithm can be used for estimating concentrations of non-reactive pollutants at 30 receptors, for averaging times of 1 to 24 hours, for up to 30 sources of each type. Calculations are performed for each hour using the specified hourly meteorological data. The PAL model is intended to assess the impact on air quality, on scales of tens of meters to several kilometers, of portions of urban areas such as shopping centers, large parking areas, and airports. Level terrain is assumed, and pollutant removal processes are ignored.

Rao (1981) gave analytical solutions of a gradient-transfer model for dry deposition of gaseous and particulate pollutants from a plume. These new diffusion-deposition algorithms were presented as analytical extensions of the Gaussian plume diffusion algorithms currently used in EPA models under various atmospheric stability and mixing conditions. The analytical gradient-transfer model treats gravitational settling and dry deposition of pollutant in a physically realistic and straightforward manner, and it is subject to the same basic assumptions and limitations associated with all Gaussian plume-type models. For details of the model and the solutions, the user is referred to Rao (1981).

This report is a User's Guide to the PAL-DS model that utilizes the plume diffusion-deposition algorithms given by Rao (1981). In the limit when pollutant settling and dry deposition veloicities are zero, these expressions reduce to the Gaussian plume diffusion algorithms of the original PAL model (Petersen, 1978). This report outlines the modifications of the PAL computer program to include deposition. Most of the information is oriented to the programmer: organization of computer program (Section 2), preparation of input data (Section 3), example problems (Section 4), and diffusion-deposition algorithms (Appendix) of the PAL-DS program.

It should be emphasized here that this report is not a complete User's Guide for the PAL-DS model. It is meant to be used together with the original User's Guide for PAL (Petersen, 1978).

SECTION 2

ORGANIZATION OF COMPUTER PROGRAM

The modification of the PAL computer program to include gravitational settling and/or deposition effects has been carried out with as few code changes as necessary. The structure of the PAL-DS program subroutines and functions, the general flow of the model, and a brief description of only those subroutines and functions not listed in the original User's Guide for PAL (Petersen, 1978) are given in this section.

STRUCTURE OF THE PROGRAM

Figure 1 shows the structure of the PAL-DS program. PAL is the main routine; it reads input data and stores the appropriate data in common with the six major subroutines. All input data for each hour are read before execution begins for any source type. If gravitational settling and/or deposition loss of pollutant are considered, subroutines RCONPD and RCONAD are used for point and area source concentrations, respectively; if not, RCONCP and RCONCA are used. All output is printed via the main routine PAL. An additional output in the PAL-DS program is a table of deposition flux at ground-level receptors. Any receptor which is not higher than 1 meter above the local ground-level elevation is defined as a ground-level receptor in the program.

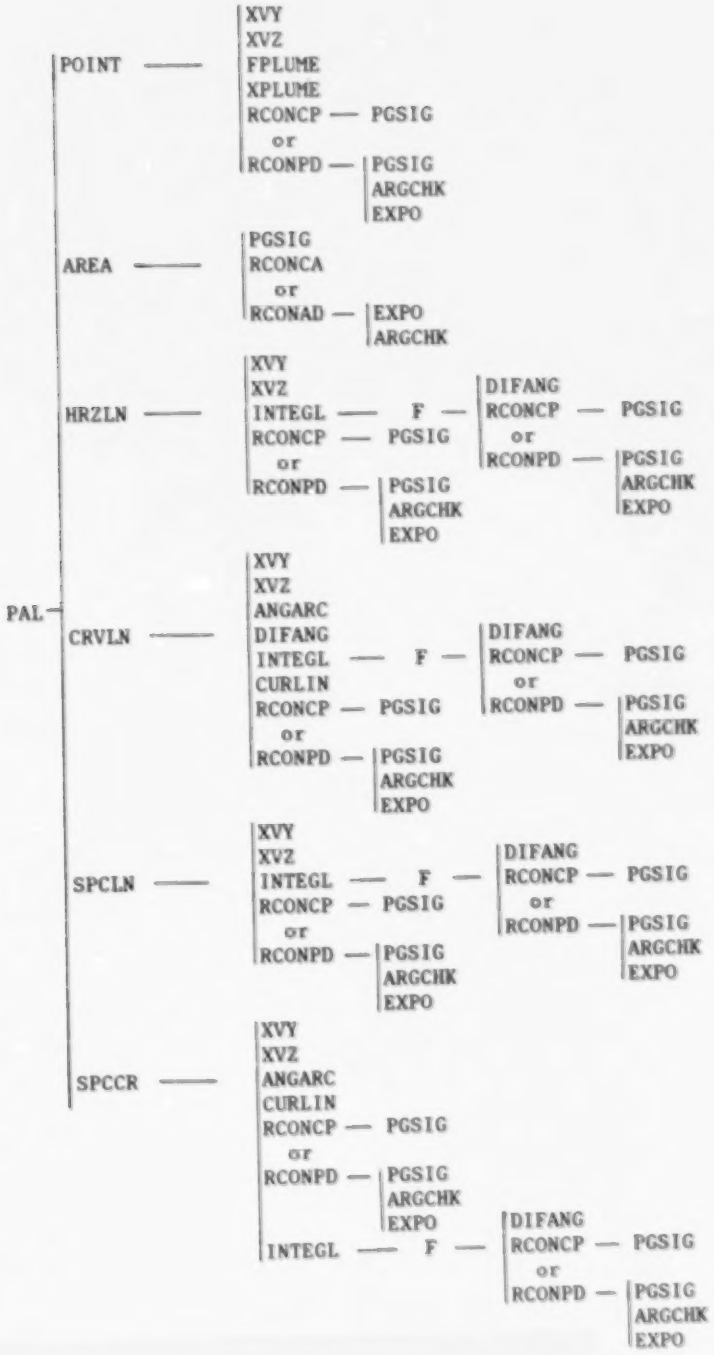

Figure 1. Structure of subroutines and functions in PAL-DS Program.

GENERAL FLOW OF THE MODEL

The main routine reads the integration accuracy specified for the area and line sources, the control information for using the various source-types, the options for the change of wind speed with height for each source-type, hourly variation in emissions, and consideration of deposition effects. If the last option is selected, the values of pollutant settling and dry deposition velocities must be specified. The source data are then read in for the source-types selected by the control information. Any number of each source-type or any combination of the six source-types may be used. All input to the program is printed as output before execution, so that a complete listing of the problem is available. Finally, receptor coordinates and meteorological data are read. The latter are required for each hour up to 24 hours. All I/O formats essentially remain the same as in the original version of PAL. Additional output tables of surface deposition flux are printed by the PAL-DS program, if the deposition option is selected.

DESCRIPTION OF NEW SUBROUTINES AND FUNCTIONS

A brief description of the new subroutines and functions not included in the original User's Guide for PAL (Petersen, 1978) is given below.

F - This function, called by INTEGL, calculates the concentration of a single point source on a special line source, a horizontal line source, a curved path source, or a special curved path source, depending on the option chosen.

INTEGL - This subroutine calculates the approximate value of a definite integral, and a relative error-bound for that value. The integration algorithm is an application of the Richardson extrapolation to the composite trapezoidal rule.

RCONAD - This subroutine, called by AREA, calculates $\chi U/Q$, the relative concentration normalized for wind speed, at any downwind receptor location due to the dispersion and deposition of gaseous or particulate pollutants from a crosswind infinite line source.

RCONPD - This subroutine, called by POINT and F, calculates $\chi U/Q$, the relative concentration normalized for wind speed, at any downwind receptor location due to the dispersion and deposition of gaseous or particulate pollutants from a continuous point source.

ARGCHK - This subroutine, called by RCONAD and RCONPD, limits the arguments of $\exp(p^2)\cdot\mathrm{erfc}(p)$ arising in the deposition algorithms (see Appendix) to avoid overflow/underflow errors in the program.

EXPO - This subroutine, called by RCONAD and RCONPD, calculates and returns $q = e^p$, if p is given. EXPO checks and limits the argument p to avoid overflow/underflow errors in the program.

SECTION 3

PREPARATION OF INPUT DATA

The sequence and formats for the input data cards of PAL-DS program are shown in Table 1. These are essentially the same as in the original version of PAL (Petersen, 1978), except for a few additions. Important among these are IDEP, W, VD at the end of card type 2. If IDEP = 1, deposition effects are ignored and the PAL-DS program reduces to the original PAL version. If IDEP = 2, deposition effects are considered using the specified values (in centimeters/second) of pollutant settling and deposition velocities, W and VD, respectively. The specification of these model parameters is discussed in the Appendix.

As before, all input data are in free format, except card 1 which is in alphanumeric 20A4 format. The free format is easy to use, but all variables on the card should be assigned values in the correct order, and separated by commas. Those input cards which are optional are noted below the card type number. A brief description of each input parameter is given in Table 1 with the appropriate units. For additional information on preparation of input data and other explanations of variables required as inputs specific to the various source-types, the user should refer to Petersen (1978).

TABLE 1. DESCRIPTION OF INPUT DATA

CARD TYPE 1 20A4 FORMAT
ALPHANUMERIC TITLE TO IDENTIFY OUTPUT.

CARD TYPE 2 PINA,PINL,IQP,IUZP,IQA,IUZA,IQLH,IUZH,IQLC,IUZC,IQLS,IUZS,
IQAC,IUZE,IAVG,IDRNL,UHGT, IDEP, W, VD

PINA	TEST FOR AREA INTEGRATION ACCURACY. PINA IS IN DECIMAL FORM.	(DIMENSIONLESS)
PINL	TEST FOR LINE INTEGRATION ACCURACY. PINL IS IN DECIMAL FORM.	(DIMENSIONLESS)
IQP	CONTROL FOR POINT SOURCES. IF IQP=1,NO POINT SOURCES. IF IQP=2,UP TO 30 POINT SOURCES CAN BE INCLUDED.	(DIMENSIONLESS)
IUZP	WIND INCREASE WITH HEIGHT FOR POINT SOURCES. IF IUZP=1,NO CHANGE OF WIND SPEED WITH HEIGHT. IF IUZP=2,CHANGE OF WIND SPEED WITH HEIGHT IN EFFECT, USING DEFAULT WIND PROFILE EXPONENTS. IF IUZP=3, CHANGE OF WIND SPEED WITH HEIGHT IN EFFECT,USING USER-SPECIFIED WIND PROFILE EXPONENTS.	(DIMENSIONLESS)
IQA	CONTROL FOR AREA SOURCES. USED THE SAME AS IQP.	(DIMENSIONLESS)
IUZA	WIND INCREASE WITH HEIGHT FOR AREA SOURCES. USED THE SAME AS IUZP.	(DIMENSIONLESS)
IQLH	CONTROL FOR LINE SOURCES.USED THE SAME AS IQP.	(DIMENSIONLESS)
IUZH	WIND INCREASE WITH HEIGHT FOR HORIZONAL LINES. USED THE SAME AS IUZP.	(DIMENSIONLESS)

IQLC	CONTROL FOR CURVED PATH SOURCES.USED THE SAME AS IQP.	(DIMENSIONLESS)
IUZC	WIND INCREASE WITH HEIGHT FOR CURVED PATH SOURCES. USED THE SAME AS IUZP.	(DIMENSIONLESS)
IQLS	CONTROL FOR SLANT LINE SOURCES.USED THE SAME AS IQP.	(DIMENSIONLESS)
IUZS	WIND INCREASE WITH HEIGHT FOR SLANT LINE SOURCES. USED THE SAME AS IUZP.	(DIMENSIONLESS)
IQAC	CONTROL FOR SPECIAL PATH SOURCES. USED THE SAME AS IQP.	(DIMENSIONLESS)
IUZE	WIND INCREASE WITH HEIGHT FOR SPECIAL PATH SOURCES. USED THE SAME AS IUZP.	(DIMENSIONLESS)
IAVG	CONTROL FOR AVERAGE CONCENTRATIONS. IF IAVG=1, NO AVERAGES ARE CALCULATED. IF IAVG=2, AVERAGE CONCENTRATIONS CAN BE CALCULATED UP TO 24 HOURS.	(DIMENSIONLESS)
IDRNL	CONTROL FOR EMISSION FACTORS. IF IDRNL=1, NO HOURLY VARIATION IN EMISSIONS. IF IDRNL=2, HOURLY VARIATION IN EMISSIONS CAN BE INCLUDED.	(DIMENSIONLESS)
UHGT	THE HEIGHT APPLICABLE TO THE WIND MEASURMENT.	(M)
IDEP	IF IDEP=1, GRAVITATIONAL SETTLING AND/OR DEPOSITION LOSS OF POLLUTANT IGNORED. IF IDEP=2, GRAVITATIONAL SETTLING AND/OR DEPOSITION LOSS OF POLLUTANT INCLUDED.	(DIMENSIONLESS)
W	POLLUTANT SETTLING VELOCITY.	(CM/SEC)
VD	POLLUTANT DEPOSITION VELOCITY.	(CM/SEC)

CARD TYPE 2A PUZ

CARD 2A IS OPTIONAL. (USER'S WIND PROFILE EXPONENTS)

PUZ	WIND PROFILE EXPONENTS FOR STABILITIES A-F RESPECTIVELY.	(DIMENSIONLESS)

CARD TYPE 3 ICARD,QP,HPP,TSP,VSP,DP,VFP,RQP,SQP,SYOP,SZOP

CARD 3 IS OPTIONAL. (POINT SOURCES)

ICARD	IF ICARD=1,MORE DATA CARDS ARE EXPECTED. IF ICARD=2,LAST DATA CARD OF THIS TYPE.	(DIMENSIONLESS)
QP	POINT SOURCE STRENGTH.	(G/SEC)
HPP	PHYSICAL STACK HEIGHT.	(M)
TSP	STACK GAS TEMPERATURE.	(DEG K)
VSP	STACK GAS VELOCITY. (VSP IS DISREGARDED IF VFP IS GREATER THAN ZERO)	(M/SEC)
DP	STACK INSIDE DIAMETER. (DP IS DISREGARDED IF VFP IS GREATER THAN ZERO)	(M)
VFP	STACK GAS VOLUME FLOW.	(M**3/SEC)
RQP	EAST COORDINATE OF STACK.	(KM)
SQP	NORTH COORDINATE OF STACK.	(KM)
SYOP	INITIAL SIGMA Y.	(M)
SZOP	INITIAL SIGMA Z.	(M)

CARD TYPE 4 ICARD,QA,HQ,RQ,SQ,DEST,DNOR,

CARD 4 IS OPTIONAL. (AREA SOURCES)

ICARD	USED THE SAME AS IN THE POINT SOURCES.	(DIMENSIONLESS)
QA	AREA SOURCE STRENGTH.	(G/SEC-M**2)
HQ	AREA SOURCE HEIGHT.	(M)
RQ	EAST COORDINATE OF S.W. CORNER.	(KM)
SQ	NORTH COORDINATE OF S.W. CORNER.	(KM)
DEST	EAST-WEST SIZE.	(KM)
DNOR	NORTH-SOUTH SIZE.	(KM)

CARD TYPE 5 ICARD,HLN,RAQ,SAQ,RBQ,SBQ,SYO,SZO,WT,WM,QLT

CARD 5 IS OPTIONAL. (HORIZONAL LINE SOURCES)

ICARD	USED THE SAME AS IN THE POINT SOURCES.	(DIMENSIONLESS)
HLN	HEIGHT OF THE LINE SOURCE.	(M)
NL	NUMBER OF LANES.(1 LANE OR AN EVEN NUMBER OF LANES)	(DIMENSIONLESS)
RAQ	EAST COORDINATE OF POINT A. (SEE FIGURE 4,	(KM)
SAQ	NORTH COORDINATE OF POINT A. APPENDIX A)	(KM)
RBQ	EAST COORDINATE OF POINT B.	(KM)
SBQ	NORTH COORDINATE OF POINT B.	(KM)
SYO	INITIAL SIGMA Y.	(M)
SZO	INITIAL SIGMA Z.	(M)
WT	TOTAL WIDTH OF LINE SOURCE.	(M)
WM	WIDTH OF THE MEDIAN.	(M)
QLT	LINE SOURCE EMISSION RATE, ONE FOR EACH LANE. ORDERING OF EMISSION RATES ARE FROM LEFT TO RIGHT WHEN LOOKING FROM POINT A TO POINT B.	(G/SEC-M)

CARD TYPE 6 ICARD,HLNS,NL,RBQS,SBQS,RMQS,SMQS,REQS,SEQS,SIYO,SIZO,WT,WM,QLTS

CARD 6 IS OPTIONAL. (CURVED PATH SOURCES)

ICARD	USED THE SAME AS IN THE POINT SOURCES.	(DIMENSIONLESS)
HLNS	HEIGHT OF CURVED PATH SOURCE.	(M)
NL	NUMBER OF LANES.(1 LANE OR AN EVEN NUMBER OF LANES)	(DIMENSIONLESS)
RBQS	EAST COORDINATE OF POINT A. (SEE FIGURE 5,	(KM)
SBQS	NORTH COORDINATE OF POINT A. APPENDIX A)	(KM)
RMQS	EAST COORDINATE OF POINT B.	(KM)
SMQS	NORTH COORDINATE OF POINT B.	(KM)
REQS	EAST COORDINATE OF POINT C.	(KM)
SEQS	NORTH COORDINATE OF POINT C.	(KM)
SIYO	INITIAL SIGMA Y.	(M)
SIZO	INITIAL SIGMA Z.	(M)
WT	TOTAL WIDTH OF PATH SOURCE.	(M)
QLTS	CURVED PATH SOURCE EMISSION RATE,ONE FOR EACH LANE. ORDERING OF EMISSION RATES ARE FROM OUTSIDE LANE TO INSIDE.	(G/SEC-M)

CARD TYPE 7 ICARD,QLS,HAS,HBS,RAS,SAS,RBS,SBS,SPDI,SPDF,SYOS,SZOS,TVSL,VSSL

CARD 7 IS OPTIONAL.(SPECIAL LINE SOURCES)

ICARD	USED THE SAME AS IN THE POINT SOURCES.	(DIMENSIONLESS)
QLS	LINE SOURCE STRENGTH, ONE LANE ONLY.	(G/SEC)
HAS	HEIGHT OF POINT A.	(M)
HBS	HEIGHT OF POINT B.	(M)
RAS	EAST COORDINATE OF POINT A.	(KM)
SAS	NORTH COORDINATE OF POINT A.	(KM)
RBS	EAST COORDINATE OF POINT B.	(KM)
SBS	NORTH COORDINATE OF POINT B.	(KM)
SPDI	VEHICLE SPEED AT POINT A.	(M/SEC)
SPDF	VEHICLE SPEED AT POINT B.	(M/SEC)
SYOS	INITIAL SIGMA Y.	(M)
SZOS	INITIAL SIGMA Z.	(M)
TVSL	VEHICLE VOLUME.	(VEH/HR)
VSSL	GROSS ESTIMATE OF VEHICLE SIZE.	(M)

CARD TYPE 8 ICARD,QLNA,HCL,RBQA,SBQA,RMQA,SMQA,REQA,SEQA,SPEI,SPEF,SIYA,SIZA TVCL,VSCL

CARD 8 IS OPTIONAL.(SPECIAL CURVED PATH SOURCES)

ICARD	USED THE SAME AS IN THE POINT SOURCES.	(DIMENSIONLESS)
QLNA	PATH SOURCE STRENGTH,ONE LANE ONLY.	(G/SEC)
HCL	PATH SOURCE HEIGHT.	(M)
RBQA	EAST COORDINATE OF POINT A.	(KM)
SBQA	NORTH COORDINATE OF POINT A.	(KM)
RMQA	EAST COORDINATE OF POINT B.	(KM)
SMQA	NORTH COORDINATE OF POINT B.	(KM)
REQA	EAST COORDINATE OF POINT C.	(KM)
SEQA	NORTH COORDINATE OF POINT C.	(KM)
SPEI	VEHICLE SPEED AT POINT A.	(M/SEC)
SPEF	VEHICLE SPEED AT POINT C.	(M/SEC)
SIYA	INITIAL SIGMA Y.	(M)
SIZA	INITIAL SIGMA Z.	(M)
TVCL	VEHICLE VOLUME.	(VEH/HR)
VSCL	GROSS ESTIMATE OF VEHICLE SIZE.	(M)

CARD TYPE 9 ICARD,RR,SR,ZR

ICARD	USED THE SAME AS IN THE POINT SOURCES.	(DIMENSIONLESS)
RR	EAST COORDINATE OF RECEPTOR.	(KM)
SR	NORTH COORDINATE OF RECEPTOR.	(KM)
ZR	HEIGHT OF RECEPTOR.	(M)

CARD TYPE 10 ICARD,WTHET,WU,MKST,WHL,WTA,DVP,DVA,DVH,DVS,DDVH,DVHA

ICARD	USED THE SAME AS IN THE POINT SOURCES.UP TO 24 HOURS OF METEOROLOGY CAN BE INPUT.	(DIMENSIONLESS)
WTHET	WIND DIRECTION.	(DEG AZIMUTH)
WU	WIND SPEED.	(M/SEC)
MKST	STABILITY CLASS.	(DIMENSIONLESS)
WHL	MIXING HEIGHT.	(M)
WTA	AMBIENT AIR SURFACE TEMPERATURE.	(DEG K)
DVP	HOURLY VARIATION OF EMISSIONS FOR POINT SOURCES.	(DIMENSIONLESS)
DVA	HOURLY VARIATION OF EMISSIONS FOR AREA SOURCES.	(DIMENSIONLESS)
DVH	HOURLY VARIATION OF EMISSIONS FOR LINE SOURCES.	(DIMENSIONLESS)
DVS	HOURLY VARIATION OF EMISSIONS FOR SPECIAL LINE SOURCES.	(DIMENSIONLESS)
DDVH	HOURLY VARIATION OF EMISSIONS FOR CURVED PATH SOURCES.	(DIMENSIONLESS)
DVHA	HOURLY VARIATION OF EMISSIONS FOR SPECIAL PATH SOURCES.	(DIMENSIONLESS)

IF IDRNL=1,(CARD 2) NO HOURLY INFORMATION NEEDED. IF IDRNL=2, THE HOURLY VARIATION OF EMISSIONS ARE GIVEN AS THE RATIO OF THAT EMITTED DURING THIS HOUR TO THE INPUT EMISSION. IF THE SAME AS THE INPUT,THE VALUE IS 1.00.

CARD TYPE 11 KTL

KTL	IF KTL=0 PROGRAM TERMINATES. IF KTL=1, START NEW PROBLEM. IF KTL=2,READ NEW RECEPTOR AND METEOROLOGY DATA. IF KTL=3,READ NEW METEOROLOGY DATA.	(DIMENSIONLESS)

SECTION 4

EXAMPLE PROBLEMS

Two example problems are provided in this section to demonstrate the use of the PAL-DS program. These examples illustrate two important deposition cases: (1) gases or fine suspended particles which deposit on the ground without gravitational settling and (2) large pollutant particles with appreciable gravitational settling velocity equal to the dry deposition velocity.

Example 1 is identical to that given in the User's Guide for PAL (Petersen, 1978, p. 28) except that deposition of a gaseous pollutant (with V_d = 1 cm/sec and W = 0) is considered here. This should allow a useful comparison of the results. Figure 2 shows the location of all sources and receptors. Table 2 shows the input data cards for this example. The latter is identical to Table 4 of Petersen (1978) except for card type 2 which has three additional variables of 2, 0., and 1.0 for IDEP, W, and VD, respectively. A computer listing of the output for this example is shown in Table 3. The output format is similar to that of Petersen (1978, p. 33) except that additional output tables of "Deposition Flux at Ground Level Receptors" are printed in units of kg/km^2-hour. It should be noted that the calculated concentrations are less here because of the deposition loss of pollutant between the sources and the receptors.

Example 2 is intended to illustrate all six types of sources available in

PAL-DS; it does not pretend to represent a realistic situation. The locations of the sources and receptors are presented in Figure 3. Some of the receptors are above ground-level. The pollutant is assumed to be total suspended particulate (TSP) matter with a deposition velocity V_d equal to the gravitational settling velocity W of 10 cm/sec. The meteorology was held constant for four hours, except for the wind direction. The wind was allowed to blow from a different quadrant each hour. Table 4 lists the input data cards for this example; the values of IDEP, W, and VD in card type 2 are specified as 2, 10., and 10., respectively. A computer listing of the output is shown in Table 5. It should be noted that, in the output tables of "Deposition Flux at Ground Level Receptors," the fluxes are calculated and printed only for those receptors whose heights above the ground are less than or equal to 1 meter.

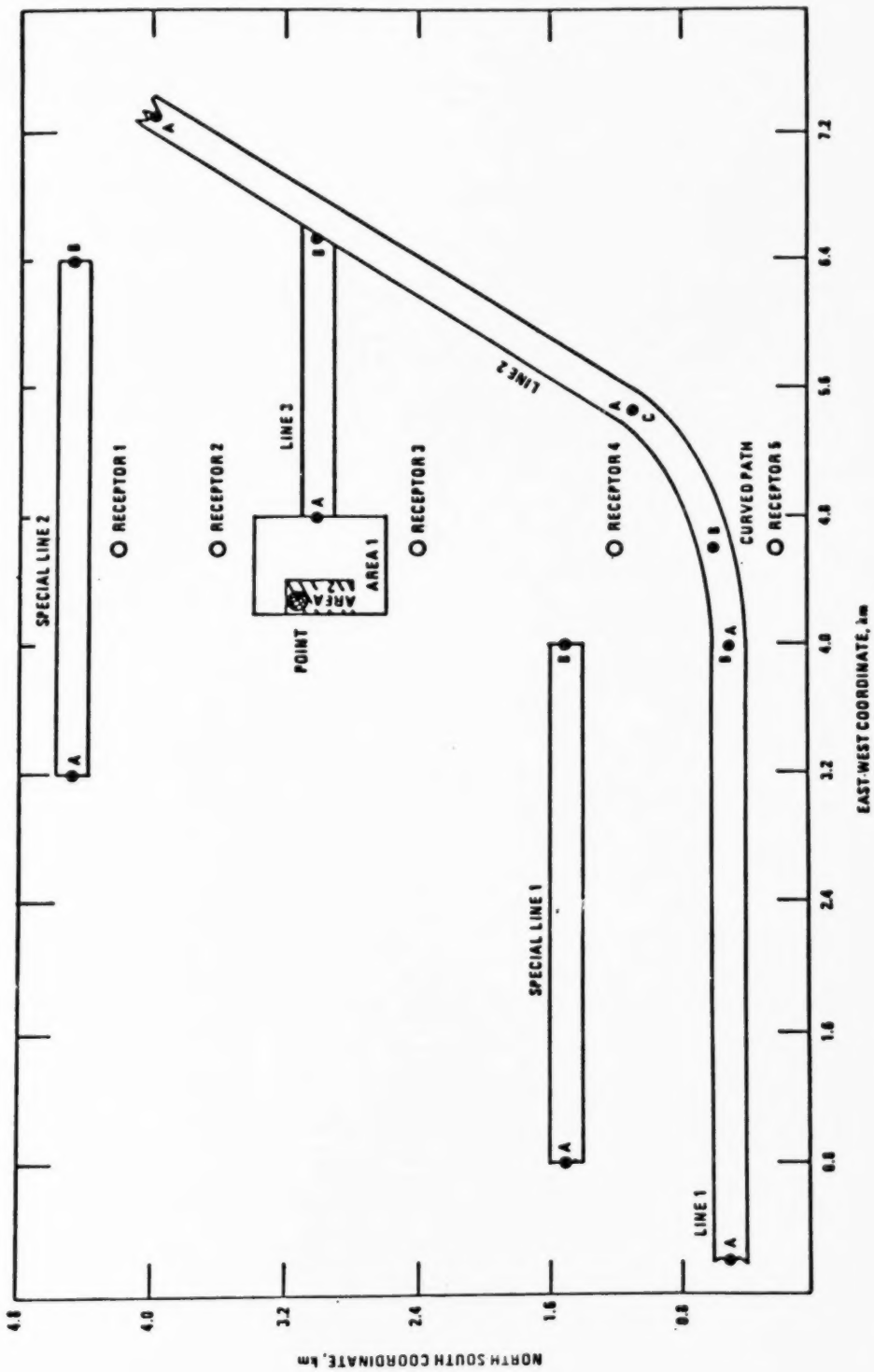

Figure 2. Schematic diagram of sources and receptors in Example Problem 1.

TABLE 2. INPUT DATA FOR EXAMPLE PROBLEM 1

CARD TYPE	
1	EXAMPLE PROBLEM FOR PAL USING GASEOUS POLLUTANT
2	0.02,0.02,2,1,2,1,2,1,2,1,2,1,1,1,2,1,5.,2,0.0,1.0
3	2,5.0,10.0,320.,0.,0.,12.,4.26,3.14,1.,1.
4	1,0.0002,0.,4.2,2.6,0.6,0.8
4	2,-0.0002,0.,4.2,2.8,0.2,0.4
5	1,0.,4,0.2,0.5,4.0,0.5,3.0,1.5,16.,0.,0.001,0.002,0.0009,0.001
5	1,0.,4,5.45,1.3,7.3,4.,3.,1.5,16,0.,0.0018,0.0018,0.0009,0.0007
5	2,0.,2,4.8,3.,6.52,3.,3.,1.5,8.,0.,0.002,0.002
6	2,0.,4,4.,0.5,4.6,0.58,5.45,1.3,3.,1.5,16.,0.,0.001,0.002,0.0009,0.001
7	1,30.,3.,3.,3.2,4.5,6.4,4.5,0.,80.,15.,6.,60.,30.
7	2,10.,3.,3.,0.8,1.5,4.,1.5,80.,0.,15.,6.,60.,30.
9	1,4.6,4.2,1.
9	1,4.6,3.6,1.
9	1,4.6,2.4,1.
9	1,4.6,1.2,1.
9	2,4.6,0.2,1.
10	1,0.,2.,4,500.,285.
10	1,350.,2.5,3,900.,289.
10	2,345.,3.,2,1100.,294.
11	3
10	1,30.,3.,4,1000.,290.
10	1,45.,6.1,4,1000.,300.
10	2,50.,3.8,3,1000.,298.
11	0

TABLE 3. COMPUTER LISTING OF OUTPUT FOR EXAMPLE PROBLEM 1

```
EXAMPLE PROBLEM FOR PAL USING GASEOUS POLLUTANT                    VERSION 81275

PINA =   0.02000 PINL =   0.02000

                SOURCE      WIND INCREASE
                INCLUDED    WITH  HEIGHT

    POINT         YES             NO

    AREA          YES             NO

HORIZONTAL
LINE SOURCE       YES             NO

    CURVE
PATH SOURCE       YES             NO

  SPECIAL
LINE SOURCE       YES             NO

  SPECIAL
PATH SOURCE        NO             NO        AVERAGE   YES   DIURNAL   NO   HEIGHT AT WIND SPEED   5.0 METERS

GRAVITATIONAL SETTLING AND/OR DEPOSITION LOSS OF POLLUTANT CONSIDERED
POLLUTANT SETTLING VELOCITY =  0.0  CM/SEC     POLLUTANT DEPOSITION VELOCITY =  1.00 CM/SEC

 WIND PROFILE EXPONENTS FOR STABILITY CLASSES (A-F)     0.15   0.15   0.20   0.25   0.40   0.60

* * * P O I N T   S O U R C E S * * *
     NO.   POINT      PHYSICAL    STACK      STACK      STACK      VOLUME       COORDINATES        INITIAL SIGMAS
           SOURCE     HEIGHT      TEMP       GAS        DIAMETER   FLOW         EAST     NORTH     Y        Q
           STRENGTH   (METERS)    (DEG-K)    VELOCITY   (METERS)   (CU M/SEC)   (KM)     (KM)      (M)      (M)
           (G/SEC)                           (M/SEC)

     1      5.00       10.0       320.0      0.0        0.0        12.00        4.260    3.140     1.0      1.0

* * A R E A   S O U R C E S * * *
     NO.   AREA       AREA        COORDINATES        AREA SIZE
           SOURCE     SOURCE      SW-CORNER
           STRENGTH   HEIGHT      EAST     NORTH     EAST-WEST  NORTH-SOUTH
           (G/SEC-M**2) (METERS)  (KM)     (KM)      (KM)       (KM)

     1   0.00020000    0.0       4.200    2.600     0.600      0.800
     2   -.00020000    0.0       4.200    2.800     0.200      0.400
```

****HORIZONTAL LINE SOURCES*****

NO.	LINE SOURCE STRENGTH (G/SEC-M)	LINE SOURCE HEIGHT (METERS)	COORDINATES POINT A EAST (KM)	POINT A NORTH (KM)	POINT B EAST (KM)	POINT B NORTH (KM)	INITIAL SIGMAS Y (M)	INITIAL SIGMAS Z (M)	NO. OF LANES	TOTAL WIDTH (METERS)	MEDIAN WIDTH (METERS)
1	0.00100000	0.0	0.200	0.506	4.000	0.506	3.00	1.50	4.	16.0	0.0
2	0.00200000	0.0	0.200	0.502	4.000	0.502	3.00	1.50			
3	0.00090000	0.0	0.200	0.498	4.000	0.498	3.00	1.50			
4	0.00100000	0.0	0.200	0.494	4.000	0.494	3.00	1.50			
5	0.00180000	0.0	5.445	1.303	7.295	4.003	3.00	1.50	8.	16.0	0.0
6	0.00180000	0.0	5.448	1.301	7.298	4.001	3.00	1.50			
7	0.00090000	0.0	5.452	1.299	7.302	3.999	3.00	1.50			
8	0.00070000	0.0	5.455	1.297	7.305	3.997	3.00	1.50			
9	0.00200000	0.0	4.800	3.002	6.520	3.002	3.00	1.50	2.	8.0	0.0
10	0.00200000	0.0	4.800	2.998	6.520	2.998	3.00	1.50			

****CURVED HORIZONTAL PATH SOURCES *****

NO.	PATH SOURCE STRENGTH (G/SEC-M)	PATH SOURCE HEIGHT (METERS)	COORDINATES POINT A EAST (KM)	POINT A NORTH (KM)	POINT B EAST (KM)	POINT B NORTH (KM)	POINT C EAST (KM)	POINT C NORTH (KM)	INITIAL SIGMAS Y (M)	INITIAL SIGMAS Z (M)	NO. OF LANES	TOTAL WIDTH (METERS)	MEDIAN WIDTH (METERS)
1	0.00100000	0.0	4.000	0.500	4.600	0.580	5.450	1.300	3.00	1.50	4	16.00	0.0

SOURCE STRENGTH FOR THE REMAINING LANES

LANE	SOURCE STRENGTH
2	0.00200000
3	0.00090000
4	0.00100000

****SLANT OR VERTICAL LINE SOURCES*****

NO.	SOURCE STRENGTH (G/SEC)	SOURCE HEIGHT (METERS) POINT A	SOURCE HEIGHT (METERS) POINT B	POINT A EAST (KM)	POINT A NORTH (KM)	POINT B EAST (KM)	POINT B NORTH (KM)	INITIAL SPEED (M/SEC)	FINAL SPEED (M/SEC)	INITIAL SIGMAS Y (M)	INITIAL SIGMAS Z (M)	TRAFFIC VOLUME (VEH/HR)	VEH. SIZE (M)
1	30.00	3.0	3.0	3.200	4.500	6.400	4.500	0.0	80.000	15.00	6.00	60.	30.0
2	10.00	3.0	3.0	0.800	1.500	4.000	1.500	80.000	0.0	15.00	6.00	60.	30.0

****RECEPTORS*****

NO.	RREC (KM)	SREC (KM)	Z (M)
1	4.600	4.200	1.0
2	4.600	3.600	1.0
3	4.600	2.400	1.0
4	4.600	1.200	1.0
5	4.600	0.200	1.0

METEOROLOGY

NO.	THETA (DEG)	U (M/SEC)	KST	HL (M)	T (DEG-K)
1.	0.	2.0	4	500.	285.
2.	350.	2.5	3	900.	289.
3.	345.	3.0	2	1100.	294.

DIURNAL VARIATIONS (FRACTIONS OF GIVEN Q)

POINT	AREA	HORIZONAL LINE	CURVED PATH	SPECIAL LINE	SPECIAL PATH
1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

*** MAXIT ITERATIONS HAVE BEEN DONE AND ACCURACY WAS NOT ACHIEVED ***

**** THE INTEGRATED VALUE FOR HOUR 2 RECEPTOR NO. 5 FROM SPECIAL LINE 2 HAS A RELATIVE ERROR OF 0.43E-01 ****

NOTE: CONCENTRATIONS ARE AFFECTED BY GRAVITATIONAL SETTLING AND/OR DEPOSITION LOSS OF POLLUTANT.

CONCENTRATIONS AT RECEPTORS

CONCENTRATIONS IN GRAMS PER CUBIC METER

HOUR	RECEPTOR NO.	RECEPTOR COORDINATES EAST	NORTH	HEIGHT	FROM POINTS	FROM AREAS	FROM HORIZONAL LINES	FROM CURVED PATHS	FROM SPECIAL LINE	FROM SPECIAL PATHS	TOTAL
1	1	4.600	4.200	1.00	0.0	0.0	0.0	0.0	1.749E-04	0.0	1.749E-04
1	2	4.600	3.600	1.00	0.0	0.0	0.0	0.0	8.167E-05	0.0	8.167E-05
1	3	4.600	2.400	1.00	1.085E-13	2.538E-03	2.281E-10	0.0	4.450E-05	0.0	2.583E-03
1	4	4.600	1.200	1.00	1.760E-06	8.284E-04	9.767E-07	0.0	3.150E-05	0.0	8.626E-04
1	5	4.600	0.200	1.00	6.949E-06	4.905E-04	1.927E-06	9.899E-05	2.567E-05	0.0	6.240E-04

CONCENTRATIONS AT RECEPTORS

CONCENTRATIONS IN GRAMS PER CUBIC METER

HOUR	RECEPTOR NO.	RECEPTOR COORDINATES EAST	NORTH	HEIGHT	FROM POINTS	FROM AREAS	FROM HORIZONAL LINES	FROM CURVED PATHS	FROM SPECIAL LINES	FROM SPECIAL PATHS	TOTAL
2	1	4.600	4.200	1.00	0.0	0.0	0.0	0.0	1.069E-04	0.0	1.069E-04
2	2	4.600	3.600	1.00	0.0	0.0	0.0	0.0	4.610E-05	0.0	4.610E-05
2	3	4.600	2.400	1.00	5.325E-06	1.305E-03	1.989E-11	0.0	2.442E-05	0.0	1.335E-03
2	4	4.600	1.200	1.00	2.442E-05	2.021E-04	1.580E-08	0.0	1.956E-05	0.0	2.461E-04
2	5	4.600	0.200	1.00	9.630E-06	6.955E-05	2.708E-08	5.383E-05	1.854E-05	0.0	1.516E-04

CONCENTRATIONS AT RECEPTORS

CONCENTRATIONS IN GRAMS PER CUBIC METER

HOUR	RECEPTOR NO.	RECEPTOR COORDINATES EAST	NORTH	HEIGHT	FROM POINTS	FROM AREAS	FROM HORIZONAL LINES	FROM CURVED PATHS	FROM SPECIAL LINES	FROM SPECIAL PATHS	TOTAL
3	1	4.600	4.200	1.00	0.0	0.0	0.0	0.0	6.786E-05	0.0	6.786E-05
3	2	4.600	3.600	1.00	0.0	0.0	0.0	0.0	2.492E-05	0.0	2.492E-05
3	3	4.600	2.400	1.00	2.418E-05	6.507E-04	6.930E-10	0.0	1.311E-05	0.0	6.880E-04
3	4	4.600	1.200	1.00	6.310E-06	5.475E-05	1.854E-08	0.0	9.529E-06	0.0	7.061E-05
3	5	4.600	0.200	1.00	1.941E-06	1.600E-05	1.897E-08	3.212E-05	1.035E-05	0.0	6.043E-05

AVERAGE CONCENTRATIONS FOR 3 HOURS.

CONCENTRATIONS AT RECEPTORS*

CONCENTRATIONS IN GRAMS PER CUBIC METER

HOUR	RECEPTOR NO.	RECEPTOR COORDINATES EAST	NORTH	HEIGHT	FROM POINTS	FROM AREAS	FROM HORIZONAL LINES	FROM CURVED PATHS	FROM SPECIAL LINES	FROM SPECIAL PATHS	TOTAL
0	1	4.600	4.200	1.00	0.0	0.0	0.0	0.0	1.166E-04	0.0	1.166E-04
0	2	4.600	3.600	1.00	0.0	0.0	0.0	0.0	5.089E-05	0.0	5.089E-05
0	3	4.600	2.400	1.00	9.836E-06	1.498E-03	3.137E-10	0.0	2.735E-05	0.0	1.535E-03
0	4	4.600	1.200	1.00	1.083E-05	3.617E-04	3.370E-07	0.0	2.019E-05	0.0	3.931E-04
0	5	4.600	0.200	1.00	6.173E-06	1.920E-04	6.578E-07	6.165E-05	1.819E-05	0.0	2.787E-04

DEPOSITION FLUX AT GROUND LEVEL RECEPTORS

DEPOSITION FLUXES IN KILOGRAMS PER SQUARE KILOMETER PER HOUR

HOUR	RECEPTOR NO.	RECEPTOR COORDINATES EAST	NORTH	HEIGHT	FROM POINTS	FROM AREAS	FROM HORIZONAL LINES	FROM CURVED PATHS	FROM SPECIAL LINES	FROM SPECIAL PATHS	TOTAL
1	1	4.600	4.200	1.00	0.0	0.0	0.0	0.0	6.297E 00	0.0	6.297E 00
1	2	4.600	3.600	1.00	0.0	0.0	0.0	0.0	2.940E 00	0.0	2.940E 00
1	3	4.600	2.400	1.00	3.907E-09	9.138E 01	8.213E-06	0.0	1.602E 00	0.0	9.299E 01
1	4	4.600	1.200	1.00	6.337E-02	2.982E 01	3.516E-02	0.0	1.134E 00	0.0	3.105E 01
1	5	4.600	0.200	1.00	2.502E-01	1.766E 01	6.939E-02	3.564E 00	9.242E-01	0.0	2.246E 01

DEPOSITION FLUX AT GROUND LEVEL RECEPTORS

DEPOSITION FLUXES IN KILOGRAMS PER SQUARE KILOMETER PER HOUR

HOUR	RECEPTOR NO.	RECEPTOR COORDINATES EAST	NORTH	HEIGHT	FROM POINTS	FROM AREAS	FROM HORIZONAL LINES	FROM CURVED PATHS	FROM SPECIAL LINES	FROM SPECIAL PATHS	TOTAL
2	1	4.600	4.200	1.00	0.0	0.0	0.0	0.0	3.849E 00	0.0	3.849E 00
2	2	4.600	3.600	1.00	0.0	0.0	0.0	0.0	1.659E 00	0.0	1.659E 00
2	3	4.600	2.400	1.00	1.917E-01	4.698E 01	7.161E-07	0.0	8.793E-01	0.0	4.805E 01
2	4	4.600	1.200	1.00	8.792E-01	7.276E 00	5.689E-04	0.0	7.041E-01	0.0	8.860E 00
2	5	4.600	0.200	1.00	3.467E-01	2.504E 00	9.749E-04	1.938E 00	6.674E-01	0.0	5.457E 00

****DEPOSITION FLUX AT GROUND LEVEL RECEPTORS****
DEPOSITION FLUXES IN KILOGRAMS PER SQUARE KILOMETER PER HOUR

HOUR	RECEPTOR NO.	RECEPTOR COORDINATES EAST	NORTH	HEIGHT	FROM POINTS	FROM AREAS	FROM HORIZONAL LINES	FROM CURVED PATHS	FROM SPECIAL LINES	FROM SPECIAL PATHS	TOTAL
3	1	4.600	4.200	1.00	0.0	0.0	0.0	0.0	2.443E 00	0.0	2.443E 00
3	2	4.600	3.600	1.00	0.0	0.0	0.0	0.0	8.970E-01	0.0	8.970E-01
3	3	4.600	2.400	1.00	8.706E-01	2.343E 01	2.495E-05	0.0	4.721E-01	0.0	2.477E 01
3	4	4.600	1.200	1.00	2.272E-01	1.971E 00	6.674E-04	0.0	3.430E-01	0.0	2.542E 00
3	5	4.600	0.200	1.00	6.989E-02	5.759E-01	6.827E-04	1.156E 00	3.726E-01	0.0	2.175E 00

AVERAGE SURFACE DEPOSITION FLUX FOR 3 HOURS.

****DEPOSITION FLUX AT GROUND LEVEL RECEPTORS****
DEPOSITION FLUXES IN KILOGRAMS PER SQUARE KILOMETER PER HOUR

HOUR	RECEPTOR NO.	RECEPTOR COORDINATES EAST	NORTH	HEIGHT	FROM POINTS	FROM AREAS	FROM HORIZONAL LINES	FROM CURVED PATHS	FROM SPECIAL LINES	FROM SPECIAL PATHS	TOTAL
0	1	4.600	4.200	1.00	0.0	0.0	0.0	0.0	4.196E 00	0.0	4.196E 00
0	2	4.600	3.600	1.00	0.0	0.0	0.0	0.0	1.832E 00	0.0	1.832E 00
0	3	4.600	2.400	1.00	3.541E-01	5.393E 01	1.129E-05	0.0	9.845E-01	0.0	5.527E 01
0	4	4.600	1.200	1.00	3.899E-01	1.302E 01	1.213E-02	0.0	7.270E-01	0.0	1.415E 01
0	5	4.600	0.200	1.00	2.222E-01	6.912E 00	2.368E-02	2.219E 00	6.548E-01	0.0	1.003E 01

****METEOROLOGY*****

NO.	THETA (DEG)	U (M/SEC)	KST	HL (M)	T (DEG-K)
1.	30.	3.0	4	1000.	290.
2.	45.	6.1	4	1000.	300.
3.	50.	3.8	3	1000.	298.

DIURNAL VARIATIONS (FRACTIONS OF GIVEN Q)

POINT	AREA	HORIZONAL LINE	CURVED PATH	SPECIAL LINE	SPECIAL PATH
1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

NOTE: CONCENTRATIONS ARE AFFECTED BY GRAVITATIONAL SETTLING AND/OR DEPOSITION LOSS OF POLLUTANT.

* * C O N C E N T R A T I O N S A T R E C E P T O R S * * *
CONCENTRATIONS IN GRAMS PER CUBIC METER

HOUR	RECEPTOR NO.	RECEPTOR COORDINATES EAST	NORTH	HEIGHT	FROM POINTS	FROM AREAS	FROM HORIZONAL LINES	FROM CURVED PATHS	FROM SPECIAL LINES	FROM SPECIAL PATHS	TOTAL
1	1	4.600	4.200	1.00	0.0	0.0	0.0	0.0	1.267E-04	0.0	1.267E-04
1	2	4.600	3.600	1.00	0.0	0.0	0.0	0.0	5.448E-05	0.0	5.448E-05
1	3	4.600	2.400	1.00	0.0	6.095E-04	3.957E-05	0.0	2.596E-05	0.0	6.751E-04
1	4	4.600	1.200	1.00	0.0	0.0	1.722E-05	0.0	6.077E-06	0.0	2.330E-05
1	5	4.600	0.200	1.00	0.0	0.0	3.958E-05	1.070E-04	2.566E-07	0.0	1.468E-04

* * C O N C E N T R A T I O N S A T R E C E P T O R S * * *
CONCENTRATIONS IN GRAMS PER CUBIC METER

HOUR	RECEPTOR NO.	RECEPTOR COORDINATES EAST	NORTH	HEIGHT	FROM POINTS	FROM AREAS	FROM HORIZONAL LINES	FROM CURVED PATHS	FROM SPECIAL LINES	FROM SPECIAL PATHS	TOTAL
2	1	4.600	4.200	1.00	0.0	0.0	0.0	0.0	7.108E-05	0.0	7.108E-05
2	2	4.600	3.600	1.00	0.0	0.0	0.0	0.0	2.982E-05	0.0	2.982E-05
2	3	4.600	2.400	1.00	0.0	3.523E-05	2.260E-05	0.0	1.770E-06	0.0	5.961E-05
2	4	4.600	1.200	1.00	0.0	0.0	3.267E-05	0.0	1.806E-11	0.0	3.267E-05
2	5	4.600	0.200	1.00	0.0	0.0	5.390E-06	1.382E-05	1.409E-16	0.0	1.921E-05

* * C O N C E N T R A T I O N S A T R E C E P T O R S * * *
CONCENTRATIONS IN GRAMS PER CUBIC METER

HOUR	RECEPTOR NO.	RECEPTOR COORDINATES EAST	NORTH	HEIGHT	FROM POINTS	FROM AREAS	FROM HORIZONAL LINES	FROM CURVED PATHS	FROM SPECIAL LINES	FROM SPECIAL PATHS	TOTAL
3	1	4.600	4.200	1.00	0.0	0.0	5.805E-29	0.0	7.104E-05	0.0	7.104E-05
3	2	4.600	3.600	1.00	0.0	0.0	7.725E-16	0.0	2.362E-05	0.0	2.362E-05
3	3	4.600	2.400	1.00	0.0	1.640E-05	2.068E-05	0.0	4.556E-07	0.0	3.753E-05
3	4	4.600	1.200	1.00	0.0	0.0	2.520E-05	1.943E-14	1.123E-10	0.0	2.520E-05
3	5	4.600	0.200	1.00	0.0	0.0	1.832E-06	5.050E-06	6.236E-14	0.0	6.882E-06

AVERAGE CONCENTRATIONS FOR 3 HOURS.

CONCENTRATIONS AT RECEPTORS*

CONCENTRATIONS IN GRAMS PER CUBIC METER

HOUR	RECEPTOR NO.	RECEPTOR COORDINATES EAST	NORTH	HEIGHT	FROM POINTS	FROM AREAS	FROM HORIZONAL LINES	FROM CURVED PATHS	FROM SPECIAL LINES	FROM SPECIAL PATHS	TOTAL
0	1	4.600	4.200	1.00	0.0	0.0	1.935E-29	0.0	8.960E-05	0.0	8.960E-05
0	2	4.600	3.600	1.00	0.0	0.0	2.575E-16	0.0	3.597E-05	0.0	3.597E-05
0	3	4.600	2.400	1.00	0.0	2.204E-04	2.762E-05	0.0	9.395E-06	0.0	2.574E-04
0	4	4.600	1.200	1.00	0.0	0.0	2.503E-05	6.476E-15	2.026E-06	0.0	2.706E-05
0	5	4.600	0.200	1.00	0.0	0.0	1.560E-05	4.196E-05	8.554E-08	0.0	5.765E-05

DEPOSITION FLUX AT GROUND LEVEL RECEPTORS

DEPOSITION FLUXES IN KILOGRAMS PER SQUARE KILOMETER PER HOUR

HOUR	RECEPTOR NO.	RECEPTOR COORDINATES EAST	NORTH	HEIGHT	FROM POINTS	FROM AREAS	FROM HORIZONAL LINES	FROM CURVED PATHS	FROM SPECIAL LINES	FROM SPECIAL PATHS	TOTAL
1	1	4.600	4.200	1.00	0.0	0.0	0.0	0.0	4.561E 00	0.0	4.561E 00
1	2	4.600	3.600	1.00	0.0	0.0	0.0	0.0	1.961E 00	0.0	1.961E 00
1	3	4.600	2.400	1.00	0.0	2.194E 01	1.425E 00	0.0	9.345E-01	0.0	2.430E 01
1	4	4.600	1.200	1.00	0.0	0.0	6.200E-01	0.0	2.188E-01	0.0	8.387E-01
1	5	4.600	0.200	1.00	0.0	0.0	1.425E 00	3.852E 00	9.238E-03	0.0	5.286E 00

DEPOSITION FLUX AT GROUND LEVEL RECEPTORS

DEPOSITION FLUXES IN KILOGRAMS PER SQUARE KILOMETER PER HOUR

HOUR	RECEPTOR NO.	RECEPTOR COORDINATES EAST	NORTH	HEIGHT	FROM POINTS	FROM AREAS	FROM HORIZONAL LINES	FROM CURVED PATHS	FROM SPECIAL LINES	FROM SPECIAL PATHS	TOTAL
2	1	4.600	4.200	1.00	0.0	0.0	0.0	0.0	2.559E 00	0.0	2.559E 00
2	2	4.600	3.600	1.00	0.0	0.0	0.0	0.0	1.073E 00	0.0	1.073E 00
2	3	4.600	2.400	1.00	0.0	1.268E 00	8.137E-01	0.0	6.370E-02	0.0	2.146E 00
2	4	4.600	1.200	1.00	0.0	0.0	1.176E 00	0.0	6.500E-07	0.0	1.176E 00
2	5	4.600	0.200	1.00	0.0	0.0	1.940E-01	4.976E-01	5.071E-12	0.0	6.916E-01

**** D E P O S I T I O N F L U X A T G R O U N D L E V E L R E C E P T O R S ****
DEPOSITION FLUXES IN KILOGRAMS PER SQUARE KILOMETER PER HOUR

HOUR	RECEPTOR NO.	RECEPTOR COORDINATES EAST	NORTH	HEIGHT	FROM POINTS	FROM AREAS	FROM HORIZONAL LINES	FROM CURVED PATHS	FROM SPECIAL LINES	FROM SPECIAL PATHS	TOTAL
3	1	4.600	4.200	1.00	0.0	0.0	2.090E-24	0.0	2.558E 00	0.0	2.558E 00
3	2	4.600	3.600	1.00	0.0	0.0	2.781E-11	0.0	8.503E-01	0.0	8.503E-01
3	3	4.600	2.400	1.00	0.0	5.903E-01	7.443E-01	0.0	1.640E-02	0.0	1.351E 00
3	4	4.600	1.200	1.00	0.0	0.0	9.070E-01	6.994E-10	4.042E-06	0.0	9.070E-01
3	5	4.600	0.200	1.00	0.0	0.0	6.594E-02	1.818E-01	2.245E-09	0.0	2.477E-01

AVERAGE SURFACE DEPOSITION FLUX FOR 3 HOURS.

**** D E P O S I T I O N F L U X A T G R O U N D L E V E L R E C E P T O R S ****
DEPOSITION FLUXES IN KILOGRAMS PER SQUARE KILOMETER PER HOUR

HOUR	RECEPTOR NO.	RECEPTOR COORDINATES EAST	NORTH	HEIGHT	FROM POINTS	FROM AREAS	FROM HORIZONAL LINES	FROM CURVED PATHS	FROM SPECIAL LINES	FROM SPECIAL PATHS	TOTAL
0	1	4.600	4.200	1.00	0.0	0.0	6.966E-25	0.0	3.226E 00	0.0	3.226E 00
0	2	4.600	3.600	1.00	0.0	0.0	9.270E-12	0.0	1.295E 00	0.0	1.295E 00
0	3	4.600	2.400	1.00	0.0	7.934E 00	9.942E-01	0.0	3.382E-01	0.0	9.266E 00
0	4	4.600	1.200	1.00	0.0	0.0	9.011E-01	2.331E-10	7.292E-02	0.0	9.740E-01
0	5	4.600	0.200	1.00	0.0	0.0	5.616E-01	1.511E 00	3.079E-03	0.0	2.075E 00

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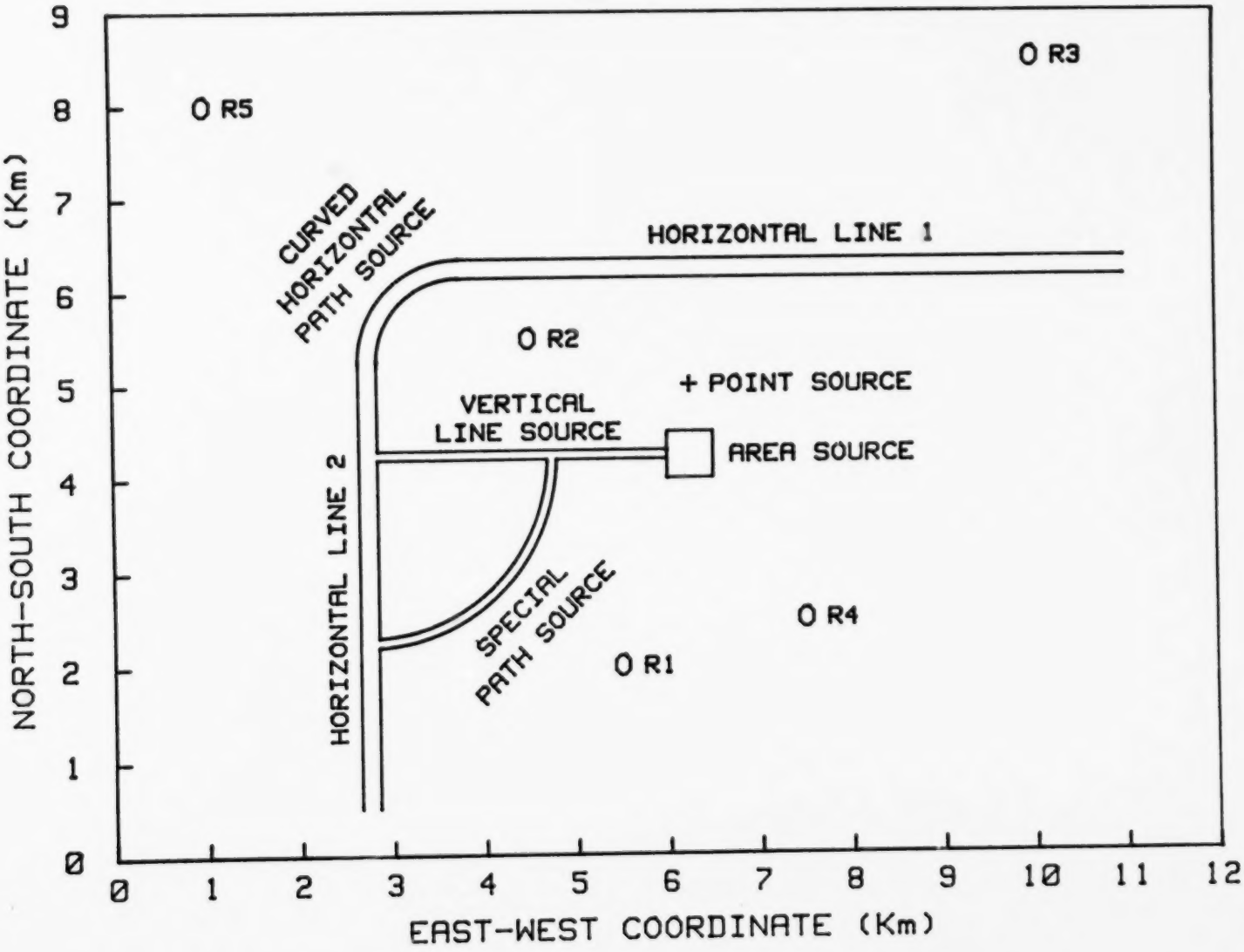

Figure 3. Schematic diagram of sources and receptors in Example Problem 2.

TABLE 4. INPUT DATA FOR EXAMPLE PROBLEM 2

CARD TYPE	
1	TEST OF PAL USING ALL SOURCE TYPES FOR TSP
2	.02,.02,2,1,2,1,2,1,2,1,2,1,2,1,1,1,5.,2,10.,10.
3	2,10.,50.,310.,0.0,0.0,12.,6.25,5.,3.,2.
4	2,.05,1.,6.,4.,.5,.5
5	1,.5,2,3.75,6.25,11.,6.25,3.,2.,10.,0.0,.001,.001
5	2,.5,2,2.75,.5,2.75,5.25,3.,2.,10.,0.0,.001,.001
6	2,.5,2,2.75,5.25,3.04,5.96,3.75,6.25,3.,2.,10.,0.0,.001,.001
7	2,10.,.2,10.,2.752,4.25,6.,4.25,40.,40.,3.,1.5,60.,5.
8	2,8.,.5,2.75,2.25,4.27,2.73,4.75,4.25,50.,50.,2.,1.5,40.,5.
9	1,5.5,2.,1.
9	1,4.5,5.5,8.
9	1,10.,8.5,1.
9	1,7.5,2.5,5.
9	2,1.,8.,1.
10	1,315.,4.,3,1000.,280.
10	1,45.,4.,3,1000.,280.
10	1,135.,4.,3,1000.,280.
10	1,225.,4.,3,1000.,280.
11	0

TABLE 5. COMPUTER LISTING OF OUTPUT FOR EXAMPLE PROBLEM 2

```
TEST OF PAL USING ALL SOURCE TYPES FOR TSP                                    VERSION 81275

PINA =   0.02000 PINL =   0.02000

                SOURCE      WIND INCREASE
               INCLUDED     WITH  HEIGHT

   POINT         YES              NO

   AREA          YES              NO

HORIZONTAL
LINE SOURCE      YES              NO

   CURVE
PATH SOURCE      YES              NO

  SPECIAL
LINE SOURCE      YES              NO

  SPECIAL
PATH SOURCE      YES              NO          AVERAGE      NO   DIURNAL    NO     HEIGHT AT WIND SPEED    5.0 METERS


GRAVITATIONAL SETTLING AND/OR DEPOSITION LOSS OF POLLUTANT CONSIDERED
POLLUTANT SETTLING VELOCITY = 10.00 CM/SEC     POLLUTANT DEPOSITION VELOCITY = 10.00 CM/SEC


 WIND PROFILE EXPONENTS FOR STABILITY CLASSES (A-F)      0.15   0.15   0.20   0.25   0.40   0.60


* * * P O I N T   S O U R C E S * * *
     NO.    POINT      PHYSICAL     STACK      STACK      STACK      VOLUME       COORDINATES        INITIAL SIGMAS
          SOURCE      HEIGHT      TEMP      GAS      DIAMETER      FLOW       EAST       NORTH       Y          Z
          STRENGTH    (METERS)    (DEG-K)   VELOCITY (METERS)     (CU M/SEC)  (KM)       (KM)        (M)        (M)
          (G/SEC)                           (M/SEC)

     1      10.00       50.0       310.0      0.0        0.0        12.00      6.250      5.000       3.0        2.0


* * A R E A   S O U R C E S * * *
     NO.      AREA        AREA          COORDINATES          AREA SIZE
            SOURCE      SOURCE        SW-CORNER
            STRENGTH    HEIGHT      EAST       NORTH     EAST-WEST  NORTH-SOUTH
          (G/SEC-M**2)  (METERS)    (KM)       (KM)      (KM)       (KM)

     1   0.05000000       1.0      6.000      4.000      0.500      0.500
```

* * H O R I Z O N T A L L I N E S O U R C E S * * *

NO.	LINE SOURCE STRENGTH (G/SEC-M)	LINE SOURCE HEIGHT (METERS)	COORDINATES POINT A EAST (KM)	POINT A NORTH (KM)	POINT B EAST (KM)	POINT B NORTH (KM)	INITIAL SIGMAS Y (M)	INITIAL SIGMAS Z (M)	NO. OF LANES	TOTAL WIDTH (METERS)	MEDIAN WIDTH (METERS)
									2.	10.0	0.0
1	0.00100000	0.5	3.750	6.252	11.000	6.252	3.00	2.00			
2	0.00100000	0.5	3.750	6.247	11.000	6.247	3.00	2.00	2.	10.0	0.0
3	0.00100000	0.5	2.747	0.500	2.747	5.250	3.00	2.00			
4	0.00100000	0.5	2.752	0.500	2.752	5.250	3.00	2.00			

* *C U R V E D H O R I Z O N T A L P A T H S O U R C E S * * *

NO.	PATH SOURCE STRENGTH (G/SEC-M)	PATH SOURCE HEIGHT (METERS)	COORDINATES POINT A EAST (KM)	POINT A NORTH (KM)	POINT B EAST (KM)	POINT B NORTH (KM)	POINT C EAST (KM)	POINT C NORTH (KM)	INITIAL SIGMAS Y (M)	INITIAL SIGMAS Z (M)	NO. OF LANES	TOTAL WIDTH (METERS)	MEDIAN WIDTH (METERS)
1	0.00100000	0.500	2.750	5.250	3.040	5.960	3.750	6.250	3.00	2.00	2	10.00	0.0

SOURCE STRENGTH FOR THE REMAINING LANES

LANE	SOURCE STRENGTH
2	0.00100000

* * S L A N T O R V E R T I C A L L I N E S O U R C E S * * *

NO.	SOURCE STRENGTH (G/SEC)	SOURCE HEIGHT (METERS) POINT A	SOURCE HEIGHT (METERS) POINT B	POINT A EAST (KM)	POINT A NORTH (KM)	POINT B EAST (KM)	POINT B NORTH (KM)	INITIAL SPEED (M/SEC)	FINAL SPEED (M/SEC)	INITIAL SIGMAS Y (M)	INITIAL SIGMAS Z (M)	TRAFFIC VOLUME (VEH/HR)	VEH. SIZE (M)
1	10.00	0.2	10.0	2.752	4.250	6.000	4.250	40.000	40.000	3.00	1.50	60.	5.0

* * S P E C I A L P A T H S O U R C E S * * *

NO.	SOURCE STRENGTH (G/SEC)	SOURCE HEIGHT (METERS)	POINT A EAST (KM)	POINT A NORTH (KM)	POINT B EAST (KM)	POINT B NORTH (KM)	POINT C EAST (KM)	POINT C NORTH (KM)	INITIAL SPEED (M/SEC)	FINAL SPEED (M/SEC)	INITIAL SIGMAS Y (M)	INITIAL SIGMAS Q (M)	TRAFFIC VOLUME (VEH/HR)	VEH. SIZE (M)
1	8.00	0.5	2.750	2.250	4.270	2.730	4.750	4.250	50.000	50.000	2.000	1.500	40.	5.0

* * R E C E P T O R S * * *

NO.	XREC (KM)	YREC (KM)	Z (M)
1	5.500	2.000	1.0
2	4.500	5.500	8.0
3	10.000	8.500	1.0
4	7.500	2.500	5.0
5	1.000	8.000	1.0

****METEOROLOGY*****

NO.	THETA (DEG)	U (M/SEC)	KST	HL (M)	T (DEG-K)
1.	315.	4.0	3	1000.	280.
2.	45.	4.0	3	1000.	280.
3.	135.	4.0	3	1000.	280.
4.	225.	4.0	3	1000.	280.

DIURNAL VARIATIONS (FRACTIONS OF GIVEN Q)

POINT	AREA	HORIZONAL LINE	CURVED PATH	SPECIAL LINE	SPECIAL PATH
1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

NOTE: CONCENTRATIONS ARE AFFECTED BY GRAVITATIONAL SETTLING AND/OR DEPOSITION LOSS OF POLLUTANT.

****CONCENTRATIONS AT RECEPTORS*****

CONCENTRATIONS IN GRAMS PER CUBIC METER

HOUR	RECEPTOR NO.	RECEPTOR COORDINATES EAST	NORTH	HEIGHT	FROM POINTS	FROM AREAS	FROM HORIZONAL LINES	FROM CURVED PATHS	FROM SPECIAL LINES	FROM SPECIAL PATHS	TOTAL
1	1	5.500	2.000	1.00	0.0	0.0	1.155E-06	1.994E-07	3.088E-06	2.405E-06	6.847E-06
1	2	4.500	5.500	8.00	0.0	0.0	2.425E-06	2.165E-06	0.0	0.0	4.590E-06
1	3	10.000	8.500	1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	4	7.500	2.500	5.00	2.989E-08	6.702E-03	5.221E-07	4.034E-07	3.731E-06	1.142E-08	6.707E-03
1	5	1.000	8.000	1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0

****CONCENTRATIONS AT RECEPTORS*****

CONCENTRATIONS IN GRAMS PER CUBIC METER

HOUR	RECEPTOR NO.	RECEPTOR COORDINATES EAST	NORTE	HEIGHT	FROM POINTS	FROM AREAS	FROM HORIZONAL LINES	FROM CURVED PATHS	FROM SPECIAL LINES	FROM SPECIAL PATHS	TOTAL
2	1	5.500	2.000	1.00	2.904E-14	1.026E-06	8.566E-07	0.0	1.583E-16	0.0	1.882E-06
2	2	4.500	5.500	8.00	0.0	0.0	4.830E-06	0.0	0.0	0.0	4.830E-06
2	3	10.000	8.500	1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	4	7.500	2.500	5.00	0.0	0.0	3.634E-07	0.0	0.0	0.0	3.634E-07
2	5	1.000	8.000	1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0

** CONCENTRATIONS AT RECEPTORS ***

CONCENTRATIONS IN GRAMS PER CUBIC METER

HOUR	RECEPTOR NO.	RECEPTOR COORDINATES EAST	NORTH	HEIGHT	FROM POINTS	FROM AREAS	FROM HORIZONAL LINES	FROM CURVED PATHS	FROM SPECIAL LINES	FROM SPECIAL PATHS	TOTAL
3	1	5.500	2.000	1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	2	4.500	5.500	8.00	7.464E-12	6.690E-03	0.0	0.0	5.502E-06	1.320E-15	6.696E-03
3	3	10.000	8.500	1.00	0.0	0.0	5.570E-11	0.0	0.0	0.0	5.570E-11
3	4	7.500	2.500	5.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	5	1.000	8.000	1.00	2.313E-08	4.723E-04	3.569E-08	1.374E-06	2.094E-06	4.169E-07	4.762E-04

** CONCENTRATIONS AT RECEPTORS ***

CONCENTRATIONS IN GRAMS PER CUBIC METER

HOUR	RECEPTOR NO.	RECEPTOR COORDINATES EAST	NORTH	HEIGHT	FROM POINTS	FROM AREAS	FROM HORIZONAL LINES	FROM CURVED PATHS	FROM SPECIAL LINES	FROM SPECIAL PATHS	TOTAL
4	1	5.500	2.000	1.00	0.0	0.0	1.190E-09	0.0	0.0	0.0	1.190E-09
4	2	4.500	5.500	8.00	0.0	0.0	2.165E-06	1.434E-19	6.036E-06	5.495E-10	8.201E-06
4	3	10.000	8.500	1.00	3.678E-06	2.652E-03	2.101E-06	2.304E-12	1.234E-06	7.582E-07	2.660E-03
4	4	7.500	2.500	5.00	0.0	0.0	2.029E-12	0.0	0.0	1.569E-26	2.029E-12
4	5	1.000	8.000	1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0

** DEPOSITION FLUX AT GROUND LEVEL RECEPTORS **

DEPOSITION FLUXES IN KILOGRAMS PER SQUARE KILOMETER PER HOUR

HOUR	RECEPTOR NO.	RECEPTOR COORDINATES EAST	NORTH	HEIGHT	FROM POINTS	FROM AREAS	FROM HORIZONAL LINES	FROM CURVED PATHS	FROM SPECIAL LINES	FROM SPECIAL PATHS	TOTAL
1	1	5.500	2.000	1.00	0.0	0.0	4.157E-01	7.179E-02	1.112E 00	8.659E-01	2.465E 00
1	3	10.000	8.500	1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	5	1.000	8.000	1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0

** DEPOSITION FLUX AT GROUND LEVEL RECEPTORS **
DEPOSITION FLUXES IN KILOGRAMS PER SQUARE KILOMETER PER HOUR

NCOB	RECEPTOR NO.	RECEPTOR COORDINATES EAST	NORTH	HEIGHT	FROM POINTS	FROM AREAS	FROM HORIZONAL LINES	FROM CURVED PATHS	FROM SPECIAL LINES	FROM SPECIAL PATHS	TOTAL
2	1	5.500	2.000	1.00	1.045E-08	3.693E-01	3.084E-01	0.0	5.700E-11	0.0	6.777E-01
2	3	10.000	8.500	1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	5	1.000	8.000	1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0

** DEPOSITION FLUX AT GROUND LEVEL RECEPTORS **
DEPOSITION FLUXES IN KILOGRAMS PER SQUARE KILOMETER PER HOUR

NCOB	RECEPTOR NO.	RECEPTOR COORDINATES EAST	NORTH	HEIGHT	FROM POINTS	FROM AREAS	FROM HORIZONAL LINES	FROM CURVED PATHS	FROM SPECIAL LINES	FROM SPECIAL PATHS	TOTAL
3	1	5.500	2.000	1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	3	10.000	8.500	1.00	0.0	0.0	2.005E-05	0.0	0.0	0.0	2.005E-05
3	5	1.000	8.000	1.00	8.326E-03	1.700E 02	1.285E-02	4.947E-01	7.537E-01	1.501E-01	1.719E 02

** DEPOSITION FLUX AT GROUND LEVEL RECEPTORS **
DEPOSITION FLUXES IN KILOGRAMS PER SQUARE KILOMETER PER HOUR

NCOB	RECEPTOR NO.	RECEPTOR COORDINATES EAST	NORTH	HEIGHT	FROM POINTS	FROM AREAS	FROM HORIZONAL LINES	FROM CURVED PATHS	FROM SPECIAL LINES	FROM SPECIAL PATHS	TOTAL
4	1	5.500	2.000	1.00	0.0	0.0	4.284E-04	0.0	0.0	0.0	4.284E-04
4	3	10.000	8.500	1.00	1.324E 00	9.546E 02	7.562E-01	8.295E-07	4.444E-01	2.765E-01	9.570E 02
4	5	1.000	8.000	1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0

IFC0021 STOP 0

REFERENCES

Petersen, W. B., 1978: User's Guide for PAL: A Gaussian-Plume Algorithm for Point, Area, and Line Sources. EPA-600/4-78-013, U.S. E.P.A., Research Triangle Park, N.C., 163 pp.

Rao, K. S., 1981: Analytical Solutions of a Gradient-Transfer Model for Plume Deposition and Sedimentation. EPA-_____, U.S. E.P.A., Research Triangle Park, N.C., 75 pp.; ATDL Contribution File No. 81/14, NOAA-ATDL, P.O. Box E, Oak Ridge, TN.

APPENDIX

DIFFUSION ALGORITHMS IN PAL-DS MODEL WITH SETTLING AND DEPOSITION EFFECTS

The analytical expressions for atmospheric concentration of a gaseous or suspended particulate pollutant, subject to deposition and/or gravitational settling, in a plume released from an elevated continuous point source are given by Rao (1981). These algorithms are based on a gradient-transfer (K-theory) model. Details of the model and the solutions can be found in that reference. Here we only list the plume diffusion-deposition algorithms applicable to the PAL-DS model under various stability and mixing conditions. Before using these new algorithms, the user must read the Appendix titled "Dispersion and Analytic Geometry Equations used in PAL" in the original User's Guide for PAL (Petersen, 1978, p. 61).

The expressions to be used in the discussions that follow are

$$g_1 = \exp\ (-\hat{y}^2) \tag{A-1}$$

$$g_2' = \exp\{-2\hat{W}(\hat{z} - \hat{H})\hat{x} - \hat{W}^2\ \hat{x}^2\}.$$
$$\left[\exp\{-(\hat{z} - \hat{H})^2\} + \exp\{-(\hat{z} + \hat{H})^2\}.\right.$$
$$\left.\left(1 - 4\sqrt{\pi}\ \hat{V}_1\ \hat{x}\ e^{\xi^2}\ \mathrm{erfc}\ \xi\right)\right] \tag{A-2}$$

$$g_3' = \sum_{N=-\infty}^{\infty} \Bigg[\exp\{-2\hat{W}\,(\hat{z} - \hat{H}_1)\,\hat{x} - \hat{W}^2\,\hat{x}^2\} \cdot \Big[\exp\{-(\hat{z} - \hat{H}_1)^2\} + \exp\{-(\hat{z} + \hat{H}_1)^2\} \cdot \left(1 - 4\sqrt{\pi}\,\hat{V}_1\,\hat{x}\,e^{\xi_1^2}\,\operatorname{erfc}\,\xi_1\right)\Big]\Bigg] \qquad \text{(A-3)}$$

For $\hat{V}_2 = 0$,

$$g_4' = (1 + 2\,\hat{x}_1^2)\,\operatorname{erfc}\,\hat{x}_1 - (2\hat{x}_1/\sqrt{\pi})\,\exp(-\hat{x}_1^2) \qquad \text{(A-4)}$$

For $\hat{V}_2 \neq 0$,

$$g_4' = (\hat{V}_1/\hat{V}_2) \cdot \exp(4\hat{V}_d\hat{V}_2\hat{x}^2)\,\operatorname{erfc}(2\hat{V}_1\hat{x}) - (\hat{W}/2\hat{V}_2) \cdot \operatorname{erfc}(\hat{W}\,\hat{x}) \qquad \text{(A-5)}$$

In the above, g_2', g_3', and g_4' are the modifications of the nondimensional functions g_2, g_3, and g_4 defined in the original User's Guide for PAL (Petersen, 1978, p. 61). Though g_4 was not explicitly defined in that reference, it can be easily seen that $g_4 = 1$. The capped quantities denote the nondimensional variables defined below:

$$\begin{aligned}
\hat{H} &= H/\sqrt{2}\,\sigma_z & \hat{H}_1 &= H_1/\sqrt{2}\,\sigma_z \\
\hat{L} &= L/\sqrt{2}\,\sigma_z & \hat{V}_d &= V_d/U \\
\hat{V}_1 &= \hat{V}_d - \hat{W}/2 & \hat{V}_2 &= \hat{V}_d - \hat{W} \\
\hat{W} &= W/U & \hat{x} &= x/\sqrt{2}\,\sigma_z \\
\hat{y} &= y/\sqrt{2}\,\sigma_y & \hat{z} &= z/\sqrt{2}\,\sigma_z \\
\xi &= \hat{z} + \hat{H} + 2\,\hat{V}_1\,\hat{x} \\
\xi_1 &= \hat{z} + \hat{H}_1 + 2\,\hat{V}_1\,\hat{x}
\end{aligned} \qquad \text{(A-6)}$$

where

H = effective height of source emission

H_1 = $H + 2 N L$

L = mixing depth or height of inversion lid

N = eddy reflection number

U = mean wind speed

V_d = dry deposition velocity of pollutant

W = gravitational settling velocity of pollutant particles

x = horizontal upwind distance of source from receptor

y,z = horizontal crosswind and vertical coordinates of receptor

σ_y,σ_z = Gaussian plume dispersion parameters in y and z directions

In the limit of $\hat{W} = \hat{V}_d = 0$, the expressions for g_2', g_3', and g_4' reduce to the expressions for g_2, g_3, and g_4 given by Petersen (1978).

POINT SOURCE

Depending on the atmospheric stability and mixing conditions, the contribution to the receptor concentration, χ_p, due to a single point source is given by one of the following equations.

For stable conditions or unlimited mixing,

$$\chi_p = \frac{Q}{U} \cdot \frac{g_1}{L_y} \cdot \frac{g_2'}{L_z} \qquad \text{(A-7)}$$

For unstable or neutral conditions, with $\sigma_z < 1.6\ L$,

$$\chi_p = \frac{Q}{U} \cdot \frac{g_1}{L_y} \cdot \frac{g_3'}{L_z} \qquad \text{(A-8)}$$

For unstable or neutral conditions, with uniform vertical mixing ($\sigma_z \geq 1.6L$),

$$\chi_p = \frac{Q}{U} \cdot \frac{g_1}{L_y} \cdot \frac{g_4'}{L} \qquad \text{(A-9)}$$

In the above,

$$L_y = \sqrt{2\pi}\ \sigma_y\ , \qquad L_z = \sqrt{2\pi}\ \sigma_z, \qquad \text{(A-10)}$$

L is the mixing depth, and Q is the point source emission rate; σ_y and σ_z are evaluated for the given distance x and the atmospheric stability class. Equations (A-7) to (A-9) are directly used in the computations for point, line, and curved path sources.

AREA SOURCE

The equations given above are used in a modified form for area sources. Integration over the area source which includes edge effects from the source region is done by considering finite line sources perpendicular to the mean wind at intervals upwind from the receptor. The concentration due to a finite line source is obtained by correcting the function f related to the concentration contribution to a receptor from an infinite crosswind line source (see Petersen, 1978, p. 65). Depending on the atmospheric stability and mixing conditions, the function f is given by one of the following equations:

For stable conditions or unlimited mixing,

$$f = g_2'/L_z \tag{A-11}$$

For unstable or neutral conditions, with $\sigma_z < 1.6\ L$,

$$f = g_3'/L_z \tag{A-12}$$

For unstable or neutral conditions, with uniform vertical mixing ($\sigma_z \geq 1.6\ L$),

$$f = g_4'/L \tag{A-13}$$

In the above, L is the mixing depth and L_z is defined in Eq. (A-10).

For application of the new diffusion-deposition algorithms to line and curved path sources, and for other useful information on the PAL model, the user should refer to Petersen (1978).

SURFACE DEPOSITION FLUX

The surface deposition flux D is calculated directly from the ground-level concentration as

$$D(x,y) = V_d \cdot \chi(x,y,0) \tag{A-14}$$

This is the amount of pollutant deposited per unit time per unit surface area. D is usually expressed as kg/km^2-hour. In the PAL-DS program, the deposition flux is calculated only at ground-level receptors; these are defined as the receptors which are not higher than 1 meter above local ground-level elevation.

SETTLING AND DEPOSITION VELOCITIES

The values of the settling and deposition velocities primarily depend on the particle diameter d. In the trivial case of $W = V_d = 0$, settling and deposition effects are negligible. For very small particles ($d < 0.1$ μm), gravitational settling can be neglected, and dry deposition occurs primarily due to nongravitational effects. In this case, $W = 0$ but $V_d > 0$. For small particles ($d = 0.1 \sim 50$ μm), $0 < W < V_d$; deposition is enhanced here beyond that due to gravitational settling, primarily due to increased turbulent transfer resulting from surface roughness. For larger particles ($d > 50$ μm), it is generally assumed that $V_d = W > 0$, since gravitational settling is the dominant deposition mechanism. When $W > V_d > 0$, re-entrainment of the deposited particles from the surface back into the atmosphere is implied, as in a dust storm, for example. The first four types of model parameters given above are widely used in atmospheric dispersion and deposition of particulate material. The deposition of gases is a special case of the particulate problem with $W = 0$. Thus, one has to carefully select the values of W and V_d for use in the models. A more complete discussion of these model parameters is given by Rao (1981).

REFERENCES

Petersen, W. B., 1978: User's Guide for PAL: A Gaussian-Plume Algorithm for Point, Area, and Line Sources. EPA-600/4-78-013, U.S. E.P.A., Research Triangle Park, N.C., 163 pp.

Rao, K. S., 1981: Analytical Solutions of a Gradient-Transfer Model for Plume Deposition and Sedimentation. EPA-_____, U.S. E.P.A., Research Triangle Park, N.C., 75 pp.; ATDL Contribution File No. 81/14, NOAA-ATDL, P.O. Box-E, Oak Ridge, TN.